In-situ test methods for assessment of surface pH of corroding sewer pipes

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IN-SITU TEST METHODS FOR ASSESSMENT OF SURFACE pH OF CORRODING SEWER PIPES

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ABSTRACT:

A method for measuring the surface pH of corroding concrete was developed in the lab and tested in the field. The method is based on direct application of pH indicator solution on the corroding surfaces. Comparison against point measurements using a flat surface pH electrode (flatrode) confirmed the accuracy of the method. Blind testing of concrete specimens exposed to different acid concentrations demonstrated that it was possible to determine the surface pH within ±0.5 pH units in the pH range of one to five. The developed method provides a simple and reliable estimate on the extent of concrete corrosion. Relatively large surface areas, e.g. an entire sewer manhole, can be sprayed and assessed within a matter of minutes.

BACKGROUND

Hydrogen sulfide related sewer corrosion is a worldwide problem. The corrosion process was recognized more 100 years ago and the underlying mechanisms has since been the subject of numerous investigations. Today these processes are reasonably well understood and a number of engineering models for predicting average corrosion rates have been developed.

However, sewer pipes and manholes represent an extremely heterogeneous environment in terms of availability of nutrients and moisture as well as redox conditions. Consequently, corrosion is in most cases unevenly distributed around the pipe circumference (e.g., Vincke et al., 2001) and inside manholes (e.g. Satoh et al., 2009). In sewer pipes, the corrosion is typically greatest along the crown and directly above the daily wastewater level (Fig. 1).

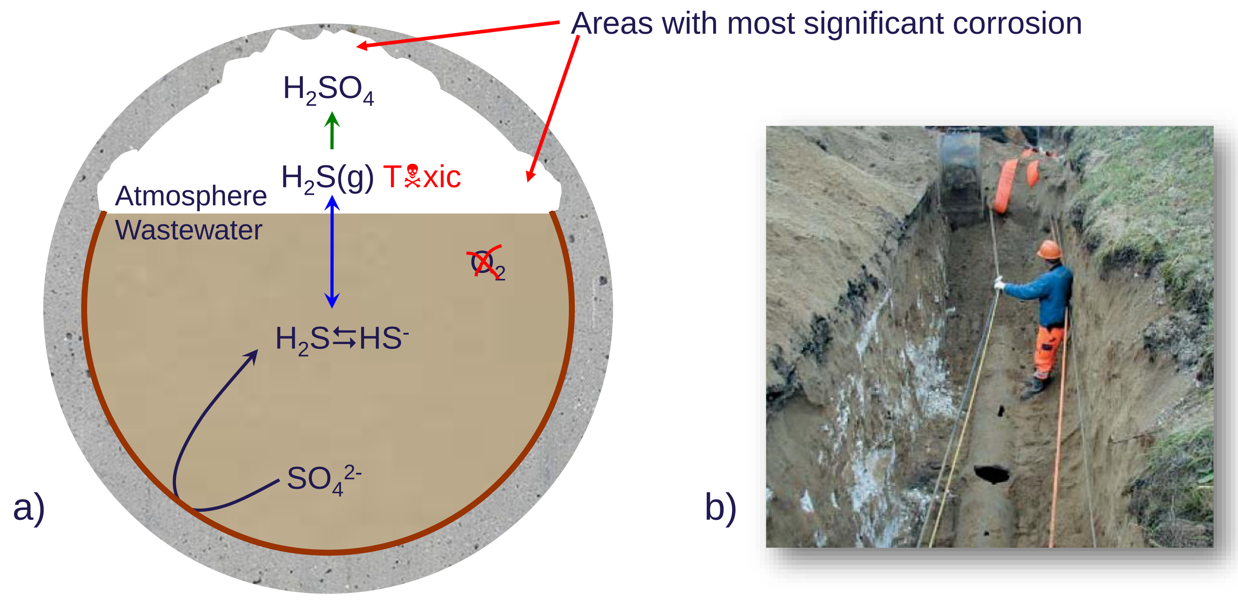

Figure 1. a) Typical distribution of corrosion along the pipe circumsphere. b) sewer pipe failure due to crown corrosion.

The surface pH of the corroding concrete is a result of the rate of sulfide oxidation (i.e., sulfuric acid production) and the rate of reaction between the concrete alkalinity and the acid. Accordingly, the surface pH is a strong indicator of the rate at which corrosion occur. Similar to the corrosion depth, it can therefore be expected that the surface pH of a corroding sewer pipe is unevenly distributed. In the literature, different methods have been applied for measuring the pH of concrete surfaces in sewers. The most widely used methods include: pH indicator strips, titration of condensate and application of flat surface glass electrodes (Islander et al., 1991; Nielsen et al., 2001).

However, such measurements are difficult to perform *in situ* and subject to various limitations in terms of poor contact between sensor and surface, absence of condensate, and restrictions on sensor orientation.

Standardized tests for the assessment of concrete carbonation exist (reaction of calcium hydroxide with carbon dioxide from the atmosphere) (BS EN 14630:2006). These depend on spraying pH indicator (phenolphthalein) onto freshly exposed surfaces of concrete broken from the structure or alternatively on powder from drill holes. The phenolphthalein indicator appears pink in contact with alkaline concrete that has not been carbonated (pH > 9) and colorless at lower levels of pH.

In the present study, a similar approach was developed for evaluating the extent of sulfide related concrete corrosion using appropriate pH indicators. A range of pH indicators were tested, including anthocyanins extracted from vegetables (red cabbage and beetroot) as well as commercially available pH indicators. The pH indicator measurements were evaluated against electrode measurements.

References:

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RESULTS AND DISCUSSION

METHOD DEVELOPMENT

Samples of corroding concrete were collected in the field (Fig. 2a). In addition, a number of concrete blocs (5 x 5 x 5 cm) were cut from sewer pipe and submerged in sulfuric acid solutions of different pH (0; 0.001; 0.01 and 0.1 M H_2SO_4) for a period of six months. For analysis, the samples were sprayed with the selected pH indicators and the surface pH was measured using a flatrode (Fig. 2b). After rigorous testing, it was concluded that a 50%/50% (w/w) mixture of bromocresol green (CAS # 76-60-8) and thymol blue (CAS # 76-61-9) in 50% ethanol provided the best discrimination of different stages of concrete corrosion (Fig. 2c).

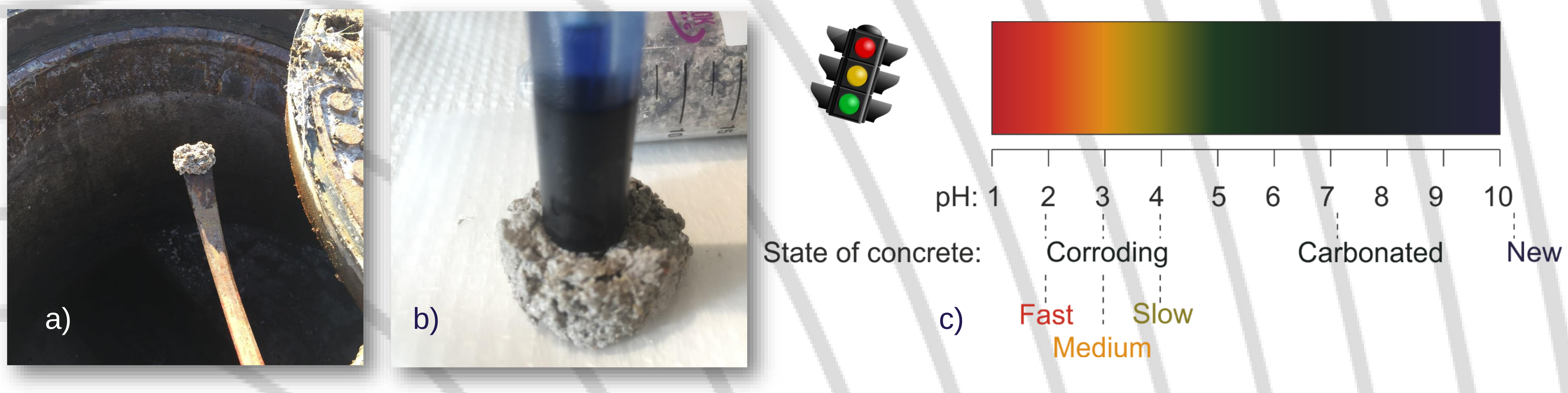


Figure 2. a) Sampling of corrosion products from a sewer manhole; b) application of a flat surface pH electrode; c) relationship between colour of the indicator and pH in the range 1-10.

The (corroding) concrete can attain different colours according to the state of corrosion, composition of the cement and type of aggregate material used, etc. This can complicate the assessment of the surface pH. It was therefore attempted to enhance the colour by digital image processing techniques. For this purpose, a set images were taken before and after application of the pH indicator. Subsequently, the two images were merged using different filter algorithms (Fig. 3).

Figure 3. Images of corroding concrete before (a) and after (b) application of the pH indicator. Colour enhancement by "divide filtering"; i.e., dividing the intensity of each color channel (R,G,B) in every pixels (c).

As evident from Figure 3, it is possible to enhance the colour by digital filtering. Preliminary testing has indicated that the method gives best results on a greyscale background (before image).

APPLICATION IN THE FIELD

The pH indicator was tested in a number of sewer manholes located downstream of force mains. The mixture was sprayed onto the concrete surfaces by means of a pressurized tank sprayer with fine mist nozzle. Within a few seconds of application, the concrete developed a color according to the surface pH (Fig. 4a and b).

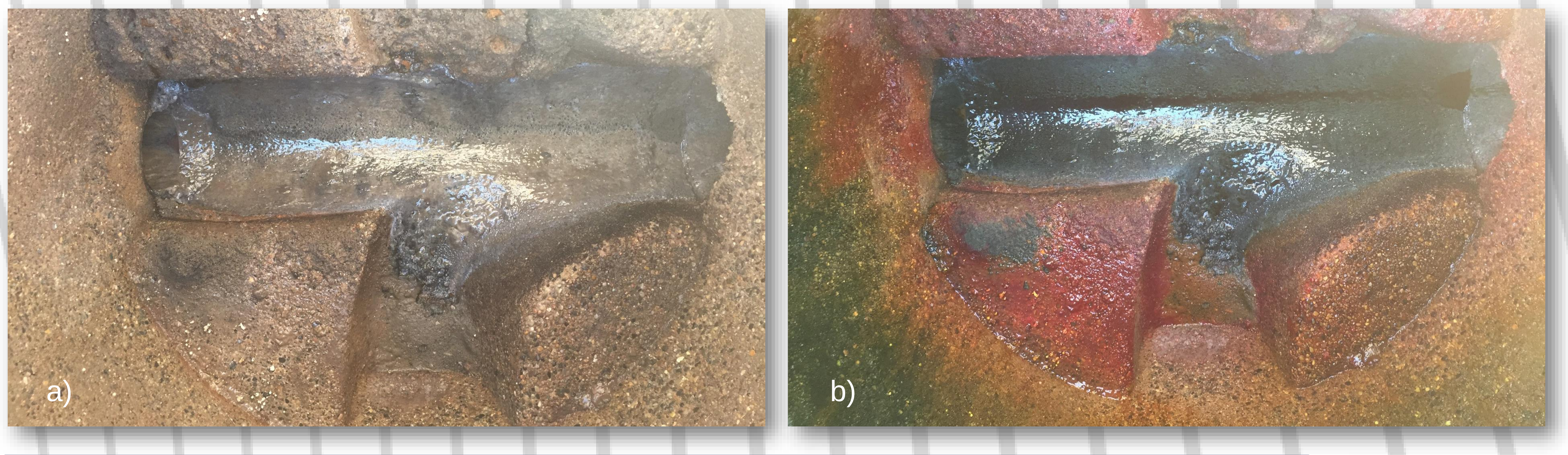
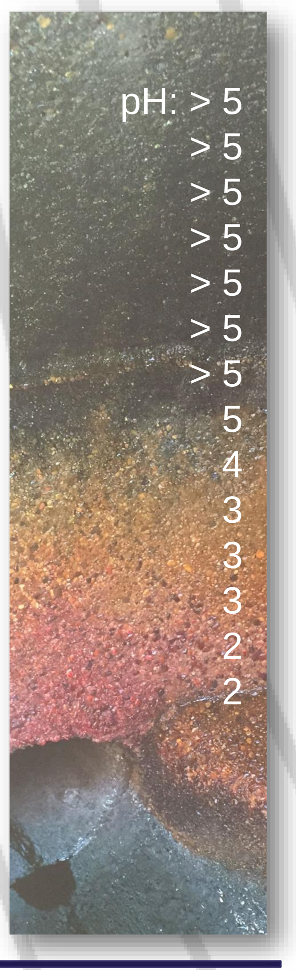


Figure 4. Before (a) and after (b) application of the pH indicator mixture in a corroding sewer manhole located downstream of a 1800 m long force main.



The example demonstrates that it is possible to estimated the surface pH even without digital image processing. Also, the results show that a significant pH gradient can exist within a single manhole. In the areas with a low surface pH (≲ 3), the aggregates of the concrete are clearly visible. Similar observations of a pH gradient has been reported by Satoh et al. (2009) who measured the surface pH at four different positions in a sewer manhole.
The method provides a simple way of assessing the state of a corroding sewer pipe. Manholes can be sprayed from above ground using simple equipment and evaluated within a matter of minutes. The method has potential to be combined with CCTV pipe inspection.

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